

The University of Chicago

GEOLOGY OF THE
EASTERN NAZARETH MOUNTAINS
PALESTINE

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

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HEINZ A. LOWENSTAM

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THE JOURNAL OF GEOLOGY

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GEOLOGY OF THE EASTERN NAZARETH MOUNTAINS, PALESTINE

I. CRETACEOUS STRATIGRAPHY

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ABSTRACT

In the Eastern Nazareth Mountains in Lower Galilee, Palestine, the Cretaceous is represented by a continuous series of marine deposits ranging from the Upper Albian to the Maestrichtian and possibly to the Danian. The uncertainty of the stratigraphic position of the Vraconian reflects the need of redefining the boundary between the Lower and Upper Cretaceous. The occurrence of "pseudo" flat-pebble conglomerates and the origin of the chert of the Cenomanian deposits are discussed. The mode of recurrent rudistite bioherms in the Lower Turonian is demonstrated. Ammonites characteristic of the Austin chalk of Texas occur in the Coniacian-Santonian beds. Differences between the Maestrichtian of the area studied and of the Palestinian standard section are discussed.

The Cretaceous deposits represent a record of the widespread Upper Cretaceous transgression beginning in late Albian time. Fluctuating conditions in Cenomanian, Turonian, and Senonian time are reflected by the character of both the sediments and faunas.

INTRODUCTION

LOCATION AND TOPOGRAPHY

The area under discussion is situated in the southern part of Lower Galilee, Palestine. The backbone of the Eastern Nazareth Mountains is formed by the Jabal Sih Range, stretching from Nazareth northeastward toward Sajara. Toward the north a gentle-sloping hilly area is bordered by the small Tur'an plain (Sahel Tur'an-Wadi Rumane). To the east the mountain complex merges morphologically into the Galilean Basin with the exception of the

isolated Lubyahill to the northeast. To the south a front range with a steep fault scarp borders the Tabor plain between Jabal Aqaba and Jabal Sartaba. Both the Jabal Sih and Jabal Sartaba merge south-eastward into a low-lying hilly area which separates them from the isolated Mount Tabor horst. Westward, toward the Western Nazareth Mountains, an arbitrary boundary line was drawn running from the Wadi Gharbi to Nazareth and from there along the Nazareth-Tiberias highway. The morphology of the Eastern Nazareth Mountains in their major features is controlled by structure.

Field work was carried on from November, 1935, to May, 1936. As a result of political disturbances the final mapping of the south-east part of Mount Tabor could not be finished.

GENERAL STATEMENT

Cretaceous deposits are widely exposed in the area studied, forming a major part of the mountain formations. The areal distribution is less extensive, however, than previously reported.¹ The Cretaceous is represented by a sequence of continuous marine deposits, ranging from the uppermost Lower Cretaceous to the higher Upper Cretaceous. The following divisions of the Cretaceous were recognized: Upper Albian-Vraconian, Cenomanian, Turonian and the Coniacian-Santonian, Campanian, and Maestrichtian of the Senonian. The occurrence of a transitional series between the Maestrichtian and the Lower Eocene beds suggests the presence of Danian equivalents. Supporting faunal evidence, however, is wanting.

UPPER ALBIAN-VRACONIAN

AREAL DISTRIBUTION

The oldest rocks in the Eastern Nazareth Mountains occur in two limited areas at the northern and eastern mountain rim, bordering the Tabor plain. Here the outcrops are located at the base of the fringing fault escarpments where the displacement exposes the deep-

¹ M. Blanckenhorn, "Kurzer Abriss der Geologie Palästinas," *Zeitschr. d. deutsch. Paläst. Ver.*, Vol. XXVI (1912), map; F. J. Fohs, "Geology and the Petroleum and Natural Gas Possibilities of Palestine etc.," *Bull. Amer. Assoc. Pet. Geol.*, Vol. XI (1927), map; P. Range, "Wissenschaftliche Ergebnisse einer geologischen Forschungsreise nach Palästina im Frühjahr 1928," *Zeitschr. d. deutsch. Paläst. Ver.*, Vol. LV (1932), map; L. Dubertret, "La Carte géologique au millionième de la Syrie et du Liban," *Rev. de géog. phys. et de géol. dynam.* (Paris, 1933), map.



FIG. 1.—Index map showing location of Eastern Nazareth Mountain area

est part of the dissected crest of the "Dabburiya anticline." The larger of the exposures lies east of the village of Iksal. The beds occupy the basal section of the mountain escarpment on either side of the lower course of the Wadi Sartaba. The smaller outcrop is located at the northwestern base of Mount Tabor, where the rocks are exposed in the road cut above the southern edge of the village of Dabburiya.

The outcrop near Iksal exposes a greater vertical range of the Vraconian than that at Mount Tabor. In both sections, however, only partial profiles can be observed because of the extensive masking of the rocks by secondary calcareous incrustations, the so-called "nari," and by soils.

PREVIOUS WORK

The outcrop northeast of Iksal was reported previously by G. S. Blake in 1928 and 1936. In 1928² the deposits were referred to the Lower Cretaceous. Subsequently³ the age was established as Upper Albian (Vraconian).

LITHOLOGY

The Vraconian rocks comprise limestones, shaly limestones, and clay beds, all of which are ferruginous. The color of the rocks is commonly deep brown, occasionally buff to green. The clay content appears to decrease toward the top of the formation, as far as can be ascertained from the partial sections. Iron, the dominant coloring agent of the rocks, is commonly concentrated in the form of limonite, as fillings of rock cavities and worm borings and as replacement of mollusk shells. Glauconite grains up to $\frac{1}{2}$ mm. in diameter are common in the fossiliferous shaly and coarse limestone beds.

THICKNESS

In the Wadi Sartaba the thickness of the exposed rock of the Upper Albian and Vraconian can be estimated as 240 feet.

FAUNA

Fossils occur in both of the outcrops. Ostreidae and Pectinidae are common at the base of Mount Tabor.⁴ In the Wadi Sartaba

² *Geology and Water Resources of Palestine* (Jerusalem, 1928), p. 11.

³ *The Stratigraphy of Palestine and Its Building Stones* (Jerusalem, 1936), p. 62.

⁴ No specific identification could be made, since the collected specimens were among those lost in the Bedouin camp of Arab Sbeih.

QUATERNARY		LOAM AND SOILS
PLEISTOCENE		DETRITAL DEPOSITS
		LOWER PLEISTOCENE BASALT
		MIDDLE PLIOCENE (ASTIAN)
TERTIARY		L. PIOCENE- ? MIOCENE BASALT
		MIDDLE EOCENE - EOCENE-CRETACEOUS CONTACT
		SENONIAN
CRETACEOUS		TURONIAN - CENOMANIAN
		VRACONIAN
		NARI
AGE ?		

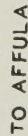


FIG. 2.—Geological map of the Eastern Nazareth Mountain area

section several fossiliferous beds occur. The highest of the fossil zones observed is crowded with *Orbitolina conica*; and in a zone 6.5 meters below, *Exogrya flabellata* outnumbers all other faunal elements. Blake⁵ reported *Pholadomya depacta* from the Wadi Sartaba section. To this can be added the following forms:

<i>Orbitolina conica</i> d'Archiac	<i>Exogrya flabellata</i> Goldfuss
Echinoid remains	<i>Tylostoma</i> cf. <i>induratum</i> Conrad
<i>Orbiculoidea</i> sp.	<i>Cerithium</i> sp.
<i>Anisocardia orientalis</i> Conrad	<i>Pseudomelania</i> sp.
<i>Lima</i> (<i>Radula</i>) <i>naamensis</i> Whitfield	Fish teeth (conchivorous)

The specifically identified forms are all known to occur in the Upper Albian–Vraconian of Syria and partly in Palestine.

CORRELATION

Anisocardia orientalis and *L. naamensis* are restricted to the Upper Albian–Vraconian. *Pholadomya depacta* (found by Blake) and *T. induratum* extend in both Palestine and Syria down to the Lower Albian, and *O. conica* ranges up into the Lower Cenomanian and *E. flabellata* as far as lower Senonian, becoming cosmopolitan during Cenomanian time. The transitional character of the faunal assemblage agrees well with the original definition of the Vraconian. Renévier⁶ defined the Vraconian as the transitional zone between the Albian and the Cenomanian (Lower-Upper Cretaceous contact). Subsequently opinions regarding its stratigraphic position have been divided. Some students of the Cretaceous included the Vraconian in the Lower Cenomanian;⁷ others considered it as Upper Albian.⁸ The same uncertainty exists concerning the position of the Vraconian in the eastern Mediterranean area, as can be seen from the correlation of the Lebanon deposits. H. Douvillé and G. Zumoffen⁹ considered the Vraconian of the Mediterranean as the equivalent of the Upper

⁵ *The Stratigraphy of Palestine . . .*, p. 64.

⁶ Cited by A. de Lapparent, *Traité de géologie* (5th ed.; Paris: Masson et Cie, 1906), Part III, pp. 1297, 1353.

⁷ *Ibid.*

⁸ A. Geikie, *Text Book of Geology* (New York: P. F. Collier & Son, 1902), Part IV, pp. 1560, 1564.

⁹ "Etudes sur les rudistes: rudistes de Sicile, d'Algérie, d'Egypte, du Liban et de la Perse," *Mém. soc. géol. France*, Vol. XVIII (1910).

Albian on the basis of faunal evidence. Blanckenhorn¹⁰ regarded it first as the base of the Cenomanian but later included it in the lower Cretaceous. In recent studies of the Syrian Cretaceous, Dubertret¹¹ accepted Douvillé's definition; and Blake,¹² who discovered Vraconian deposits in Palestine, followed the same correlation. The usage of headings like "Albian" (Vraconian)¹³ demonstrates clearly the need for clarification of the stratigraphic problems involved. The present writer is well aware of the fact that the small faunal assemblage, as well as the lack of the characteristic zone fossils—for example, *Knemiceras syriaca* and *Heteraster delgadoi*—does not permit the generalization of apparent transitional character as deduced from the few faunal elements. The question whether the Vraconian stage should be retained as a stratigraphic unit must be answered by a re-study of the European type sections. With respect to the Syrian-Palestine deposits it appears likely that a transitional fauna of the character originally defined by Renevier may well exist, since the Upper Albian represents the initial phase of a continuously spreading sea transgression culminating in the Upper Cretaceous. Studies of fossiliferous Upper Albian-Lower Cenomanian sections in Syria and Palestine are greatly desired both for the determination of the vertical range of all the faunal elements and for the succession of faunal assemblages. The results of such a study would demonstrate whether or not a transitional Vraconian stage is recognizable, which should be separated from the Upper Albian. Until such a study has been carried out, the deposits under discussion are provisionally classified as Upper Albian and Vraconian.

CENOMANIAN

GENERAL STATEMENT

The Upper Albian-Vraconian strata are conformably overlain by a great thickness of Cenomanian rocks. The outcrops are commonly characterized by steep escarpments and narrow wadi gorges, resulting from the hardness of the predominant dolomitic rock.

¹⁰ "Die fossilen Gastropoden und Scaphopoden der Kreide von Syrien-Palästina," *Palaeontographica*, Vol. LXIX (1927), p. 103; "Die Bivalven der Kreideformation von Syrien-Palästina," *ibid.*, Vol. LXXXI, Part A (1934), p. 164.

¹¹ *Op. cit.*

¹² *The Stratigraphy of Palestine . . .*, p. 64.

¹³ *Ibid.*

AREAL DISTRIBUTION

Continuous belts of exposures occur at the mountain flanks bordering the Tabor and Tur'an plains. The southern mountain escarpment facing the Tabor plain is composed of Cenomanian rocks, which extend eastward into the hilly area between Mount Tabor and Jabal Sih. Toward the Galilean Basin this outcropping belt is delimited by the Tabor fault. To the south the Mount Tabor horst is entirely built up of Cenomanian rocks, which at the northwestern flank are separated from the main mass by the Arab Sbeih fault. Extensive exposures border the Tur'an plain. The fault scarps of the Jabal Tur'an to the north and the low-lying belt at the mountain flank to the south consist of Cenomanian strata. Scattered outcrops occur in the mountain interior along the northern fault scarp of the Jabal Sih and in the eroded core of the domelike anticline of Bir Baiyin. In the hilly area north of Mount Tabor two small exposures are located in the cuts of the Wadi M'qata.

PREVIOUS WORK

Reviewing previous correlations of the sequence considered as Cenomanian, O. Fraas¹⁴ reported that the Cretaceous rocks on the top of Mount Tabor are comparable with the Maestrichtian limestones. On the first detailed map of Palestine, Blanckenhorn¹⁵ referred the strata at the northern and southern mountain rim to the Cenomanian-Turonian, both of which were mapped as one unit. In a subsequent report Blanckenhorn¹⁶ recorded the presence of both the Cenomanian and Turonian at Mount Tabor. Since the youngest deposits of the Mount Tabor section are late Cenomanian in age, it is evident that Blanckenhorn referred parts of the Upper Cenomanian deposits to the Turonian. On Range's¹⁷ geological sketch map of Galilee the age of the same areas marked by Blanckenhorn as Cenomanian-Turonian was limited to Turonian. This change was based

¹⁴ *Aus dem Orient, I. Geologische Beobachtungen am Nil, auf der Sinai-Halbinsel und in Syrien* (Stuttgart: Ebner & Seubert, 1867), p. 71.

¹⁵ "Kurzer Abriss der Geologie Palästinas," *op. cit.*, map.

¹⁶ *Syrien, Arabien und Mesopotamien, Handbuch der reg. Geol.*, Vol. V, No. 17 (1914), p. 192.

¹⁷ *Op. cit.*

on L. Picard's¹⁸ age determination of the western part of the southern belt. Picard's suggestion of a Turonian age was based on lithologic criteria and the contact relation to the overlying rocks, which he regarded as Santonian in age (see discussion of the Turonian). Detailed Cenomanian sections from the Jabal Aqaba and Mount Tabor were recorded by Blake.¹⁹ The strata below the so-called "Mizihelu"²⁰ were referred to the Cenomanian (Jabal Aqaba), and at Mount Tabor the sequence was subdivided into an Upper and Lower Cenomanian complex. Rudistites, reported from the basal "Upper Cenomanian" of the latter section, are the first recorded Cenomanian fossils from the entire Nazareth Mountains.

LITHOLOGY

The Cenomanian deposits comprise a well-bedded series of brown to buff-colored dolomites, dolomitic limestones, and limestones. The dolomites and dolomitic limestones form the dominant rock component. Pure limestones occur irregularly interbedded between the dolomites. Lateral gradation of dolomites into limestones and vice versa are common phenomena. The variability of the different rock components vertically is indicated by comparison of three detailed sections, two given by Blake²¹ from the Mount Tabor and the Jabal Aqaba and one given by Picard²² from the Western Nazareth Mountains, northeast of Ginegar.

Locally, slightly argillaceous limestones, thin shale bands, and marls are present. The shale bands occur in the "presumably upper part of the Cenomanian," in a bore section²³ in the southern Tur'an plain. The occurrence of marls was reported from the basal Upper Cenomanian of Mount Tabor by Blake.²⁴ The argillaceous deposits are not limited to a single zone but occur locally in various parts of the sequence.

¹⁸ "Zur Geologie der Kischon-Ebene," *Zeitschr. d. deutsch. Paläst. Ver.*, Vol. LI (1928), pp. 7-8.

¹⁹ *The Stratigraphy of Palestine . . .*, p. 58.

²⁰ See p. 834.

²¹ *The Stratigraphy of Palestine . . .*, p. 58.

²² *Op. cit.*, p. 8.

²³ Bore log and stratigraphic interpretation, communicated by Blake in a letter May 7, 1937.

²⁴ *The Stratigraphy of Palestine . . .*, p. 58.

Intraformational conglomerates and breccias were found locally in the upper part of the Cenomanian sequence, in the highway cut south of Nazareth, in the Wadi Sartaba, south of Ayun Shain, at the southeastern flank of Mount Tabor, and in Cenomanian boulders in the Tur'an plain. The intraformational conglomerates of Mount Tabor and in the Tur'an plain appear noteworthy for the derivation of the pebbles. At Mount Tabor the pebbles occur in a zone which is crowded with silicified pelecypod and gastropod shells. A large number of the pelecypod shells are fragmentary, well rounded, and abraded to such an extent that the original surface markings have been nearly obliterated. The associated pebbles are flat and show rounded edges like those of flat-pebble conglomerates. This association with the abraded shell fragments suggests that the pebbles may have been originally shell fragments whose surface markings have been entirely removed. No shell structure was found in sectioned pebbles because of the obliteration of structural details.

Loose boulders in which the pebbles occur are apparently derived from the eastern flank of the Jabal Tur'an, but a brief search in this region, which lies outside of the area studied, failed to locate the deposits *in situ*. Most of the larger constituents of the boulders are flat pebbles and fragments of colonial corals of the Helioporacea type. The interstitial matrix is predominantly composed of small pebbles, grading into a "pebble sand." There are all gradations from completely polished flat pebbles to similar-shaped fragments of uncorroded coral colonies. Evidence that the flat pebbles were derived from corallite fragments was found in the presence of coral structure in small depressions on the otherwise smooth and polished pebbles and by the presence of coral structure in sectioned specimens entirely free of such surface indications. The shaping of the pebbles was favored by the longitudinal cleavage along separating walls of tube-shaped individual corallites. It is proposed to call this pebble type "pseudo" flat pebble.

Pseudo flat pebbles may be derived from fragments of colonial corals of the morphological²⁵ type described, as well as from pelecyp-

²⁵ On the basis of the closely related morphology similar pseudo flat-pebble conglomerates should be found around the Paleozoic "bioherms" of *Favosites* and related coral forms and possibly of *Chaetetes*.

pods with minor curvature, by abrasion and corrosion in a rough-water environment. The assemblage of densely crowded coral fragments and pseudo flat pebbles in the boulders suggests derivation from the talus material of a coral reef. If so, the source area (the reef) and the deposition area of the pseudo flat pebbles (the adjacent sloping edge of the reef) were not far from one another. The resem-



FIG. 4.—Jabal Kafsi with Wadi Kafsi

blance to the typical flat pebble was achieved by abrasion²⁶ in the rolling sea which entirely obliterated the surface markings of the

²⁶ The extent of the abrasion period, necessary to obliterate the surface markings of the coral structure, appears to depend largely upon the part of the reef from which the particles have been derived. Fragments derived from the living zone of the reef, where the relatively strongest morphological differentiation exists, have to undergo the longest corrosion process. Alterations take place in the dead part of the reef, partly in the form of solution and erosion and partly in the form of cementation and incrustation. These processes result in a flattening of the surface of the dead reef. The abrasion period of fragments derived from the dead part of the reef will be considerably shorter, especially if the particles are relatively free of secondary borings common in this part of the reef.

coral fragments. The association of the pseudo flat pebbles with small well-rounded and polished pebbles suggest a relatively long phase of abrasion. The mode of forming of the pseudo flat pebbles explains, however, the unusual assemblage of flat and well-rounded pebbles.

Chert occurs in separate areas at different horizons. At the southern fault scarp between Jabal Aqaba and Jabal Chamsa the cherts are confined to the lower part of the Cenomanian sequence. There is one continuous zone which consists of several bands of nodular and lenticular cherts intercalated in the dolomite. To the west the zone ends above in a thin jasper bed (Jabal Kafsi). At the western margin of the occurrence, the local development of a second zone of nodular chert was observed, 10 meters higher up. At Mount Tabor and in the hilly area to the north at the Wadi Maqam esh S'hab cherts occur in the upper part of the Cenomanian sequence. Several bands of nodules and large flat lenticles (Wadi Maqam esh S'hab) are developed.

Generally, the nodules appear to be devoid of organic inclusions, although at the occurrence between Jabal Aqaba and Jabal Chamsa abundant fossiliferous nodules were found. The majority of these contain sponge spicules and a few foraminifera. Radiolarians are also common. The abundance of the spicules in the different nodules varies, some being crowded with spicules which form layer-like masses up to 19 mm. in thickness. There is no lateral, marginal decrease in the thickness of the spicule masses; one gains the impression of a laterally interrupted layer. The spicule masses show lack of orientation. Monactinellid elements among the spicules are dominant. Corrosion marks on radiolarian skeletons and spicules with enlarged canals are common.

A few nodules show a meshwork-like structure. In some places this meshwork appears to be formed by unoriented sponge spicules, whose outlines are indistinct. Locally, a few completely preserved spicules were detected.

An associated chert type is characterized by concentrically banded nodules. They are commonly devoid of organic remains. In one case, however, two minute gastropods were found in the center be-

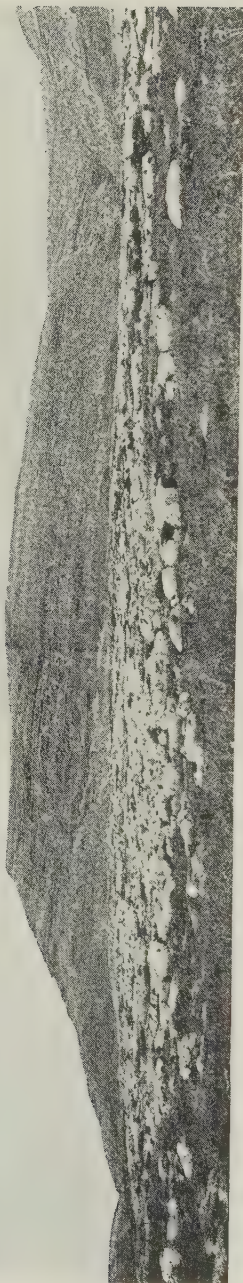


FIG. 5.—Southern fault scarp of Jabal Kafsi, as seen from the Tabor Plain

tween indeterminable fragments of megascopically visible fossils and molds of echinoid remains on the surface.

The fossil content of the chert nodules furnishes some information about the depth of water and sedimentation conditions and, as far as the sponge remains and radiolarians are concerned, about the agent precipitating the silica. The abundance of sponge spicules suggests bioherms of siliceous sponges. Crowding of the sponges seems to be indicated by the presence of the few minute gastropods and echinoids. "Dwarf" faunas commonly are associated with such types of sponge bioherms and have been explained as adaptations to the small cavities and passages of the bioherms.²⁷ The predominance of monactinellid elements among the spicules permits the conclusion that the reefs developed in comparatively shallow water. The lack of orientation of the spicule masses suggests a still-water environment. The rate of sedimentation must have been slower than the rate of disintegration of the soft parts of the sponges, since detached spicules alone are present. Spicules with enlarged axial canals and solution marks on radiolarian skeletons indicate a sufficiently long post-mortem exposure to permit incipient solution by the chemical agents of the sea water which act on amorphous silica. The nodules exhibiting a meshwork-like structure seem to represent the fixation of an advanced stage of solution. If so, this type can be regarded as a transitional stage toward complete solution of the exposed skeleton parts. The variable degree of solution indicates that it depends upon certain local conditions, which vary from place to place. Possibly, the degree of surface exposure of the skeleton material in various parts of the deposit may be the controlling factor.

G. M. Lees²⁸ in 1928 said, in a general discussion of the chert beds of Palestine, that "the silica appears to have been precipitated directly from the sea water and not through the agency of silica secreting organisms, of which there is a notable lack." But the abundance of sponge spicules and the presence of radiolarians indicate that the silica of the chert occurrence under discussion was precipitated by

²⁷ E. Dacqué, *Grundlagen und Methoden der Palaeogeographie* (Jena: Gustav Fischer, 1915), p. 236.

²⁸ "The Chert Beds of Palestine," *Proc. Geol. Assoc. London*, Vol. XXIX (1928), p. 456.

silica-secreting organisms. It may be objected that the quantity of observed sponge spicules and radiolarians is not sufficient to account for all the silica of the chert nodules. The quantitative deficiency expressed by the lack of organic remains in parts of the chert zone must not be regarded as counterevidence. L. Cayeux²⁹ cites a number of recent observations which indicate that sponge spicules can be easily dissolved on the sea floor if long enough exposed. Evidence of much solution has already been presented. The nodule type, containing layer-like masses of sponge spicules, indicates that originally continuous layers of spicules were present. The dolomites and dolomitic limestones in which the nodules are now enclosed are free from siliceous material. It is therefore evident that a considerable portion of the original spicule layers has been dissolved, the nodules being local remnants of the former spicule layers which were cemented and enveloped by silica. The latter was derived from the desilicified parts of the former skeleton layers by local solution and lateral migration. The limited extent of the chert horizons both horizontally and vertically could correspond with the original extent of the bioherms.

Whether this chertification took place entirely on the sea floor or epigenetically cannot be decided on the basis of the collected data. The concentrically banded cherts indicate considerable duration of the forming process. This chert type has been explained by A. Schwartz³⁰ and N. L. Taliaferro³¹ as representing a separate generation of chert for each of the bands which are not diffusion rings ("Liesegang rings"), as thought by W. Winkler.³² How rapidly the formation of these bands followed each other remains uncertain. It is also doubtful if the forming of the nucleus of the banded chert was contemporaneous with the forming of the spicule-bearing nodules. Since the few fossils found had a calcareous skeleton, the banded

²⁹ "Les Roches sédimentaires de France: roche silicieuses: la carte géologique détaillée de la France," *Mém. Paris* (1928), p. 565.

³⁰ "Zur Bildung der Feuersteine," *Senckenbergiana*, Vol. XI (1929), pp. 56-57, 159-92.

³¹ "Contraction Phenomena in Cherts," *Bull. Geol. Soc. Amer.*, Vol. XLV (1934), pp. 189-232.

³² "Über die Bildung mesozoischer Hornsteine: Ein Beitrag zur Sedimentpetrographie der Julischen Alpen," *Tscherm. min. u. petrog. Mitt.*, Vol. XXXVIII (1925).

chert could be supposed to have formed after the desilicification of the sponge-spicule layers.

The fossiliferous bed at the southeastern flank of Mount Tabor and the loose boulders in the Tur'an plain mentioned in connection

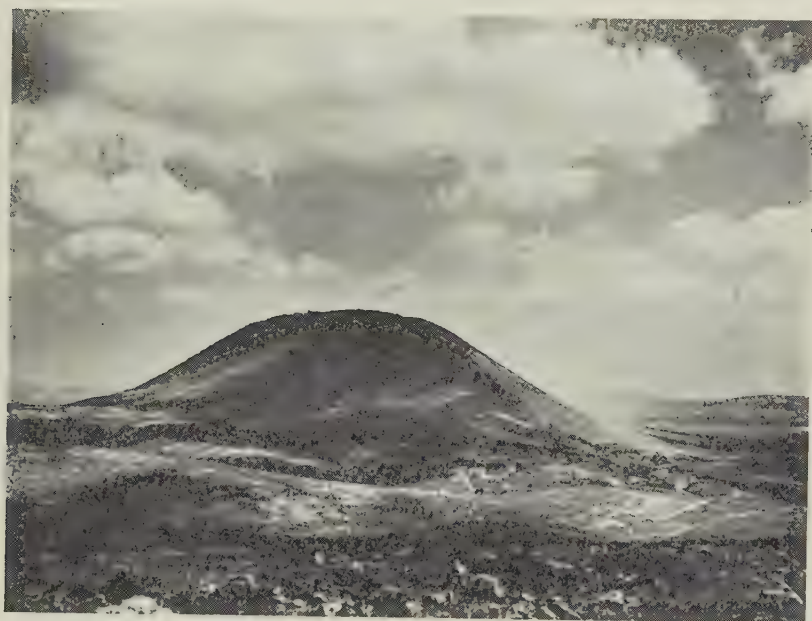


FIG. 6.—Mount Tabor seen from the east slope of Jabal Sartaba

with the description of the pseudo flat-pebble conglomerate consist of silicified limestones. They correspond to the "secondary quartzites" of Lees.³³

THICKNESS

The total thickness of the Cenomanian in the Wadi Sartaba section is 450 meters.

FAUNA

The Cenomanian deposits are sparingly fossiliferous. Fossils occur mainly in form of casts and molds and are generally poorly preserved. Lenslike concentrations of fossil remains were found sporadically.

The earliest remains observed in these Cenomanian strata occur

³³ *Op. cit.*, p. 455.

in chert nodules at the southern mountain escarpment. The faunal assemblage representing a sponge bioherm has been mentioned above in the discussion on the origin of the chert nodules. The radiolarians form the only faunal element which may permit specific identification. They have not as yet been studied.

A prolific fauna was found in the highway cuts (highway: Nazareth-Affula) on the southern mountain escarpment. The fossils occur in a lenslike body which extends horizontally for nearly 40 meters and has an exposed thickness up to 1 meter. The fossil deposit occurs 190 meters below the top of the Cenomanian and is stratigraphically higher than the fossiliferous nodules mentioned above. The fauna contains the following forms:

? <i>Trochosmilia</i> sp.	<i>Delphinula porteri</i> Blanckenhorn
<i>Serpula</i> sp. nov.	<i>Natica</i> sp.
<i>Avicula cenomanensis</i> d'Orbigny	<i>Turritella</i> sp.
<i>Nucula</i> sp.	<i>Nerinea</i> cf. <i>abeihensis</i> Blanckenhorn
<i>Leda</i> sp.	<i>N. cochleaeformis</i> Conrad
<i>Cucullaea</i> sp.	<i>N. (Nerinella)</i> cf. <i>schicki</i> Fraas
<i>Arca</i> sp. nov.	<i>N. longissima</i> Reuss
<i>Cardita nicaisei</i> Coquand	<i>Cerithium</i> cf. <i>intercalatum</i> J. Boehm
<i>Astarte</i> sp.	<i>Cerithium</i> aff. <i>sejunctum</i> Zekeli
<i>Cardium</i> sp.	<i>Mesostoma shalemi</i> Blanckenhorn
<i>Protocardia</i> cf. <i>coquandi</i> Seguenza	<i>Rostellaria</i> cf. <i>bekariensis</i> Blanckenhorn
<i>Anisocardia aquilina</i> Coquand	<i>Hastula</i> (?) <i>aciformis</i> Blanckenhorn
<i>Dosinia delettrei</i> Coquand	<i>Actaeonella salomonis</i> Fraas
<i>Venus reynesi</i> Coquand	<i>A. syriaca</i> Conrad ³⁴
<i>Dentalium</i> sp.	

The bulk of the specifically identified forms is confined to the Cenomanian, including the following: *A. cenomanensis*, *C. nicaisei*, *A. aquilina*, *D. porteri*, *N. longissima*, *M. shalemi*, *H.*(?) *aciformis*, and *A. syriaca*. Of these forms, *H.*(?) *aciformis*, *D. porteri*, and *A. syriaca* occur exclusively in the Lower Cenomanian. *H.*(?) *aciformis*, *N. cochleaeformis*, and *A. syriaca* are forms which Blanckenhorn³⁵ considers as index fossils of the Lower Cenomanian. According to Blake,³⁶ however, *H.*(?) *aciformis* and *N. cochleaeformis* are

³⁴ Blanckenhorn, "Die Bivalven . . . ," *op. cit.*, summarizing table, used for all correlated age ranges.

³⁵ "Geologie Palästinas nach heutiger Auffassung," *Zeitschr. d. deutsch. Paläst. Ver.* Vol. LIV (1931), p. 9.

³⁶ *The Stratigraphy of Palestine* . . . , p. 54.

"characteristic fossils" of the upper complex of the Lower Cenomanian. *H.(?) aciformis* ranges from the Vraconian³⁷ to the Upper Cenomanian.³⁸ Consequently, it cannot be considered as an index fossil.

Of the specifically identified forms, 83 per cent have a pronounced Mediterranean character. Of these, 44 per cent are restricted to the eastern Mediterranean countries. There is a subordinate influx of European forms, indicated by the presence of *A. cenomanensis*, *N. longissima*, and a form which is closely allied with *C. sejunctum*.

The remaining fossils, collected from various horizons in the area studied, were found to be either too poorly preserved for specific identifications or noncharacteristic, owing to their considerable vertical range.

Fossils differing from those collected in the Eastern Nazareth Mountains were found in loose, silicified boulders in the wadis of the Tur'an plain. These boulders, which were probably brought down from the eastern flank of Jabal Tur'an, have been mentioned above in the discussions on the pseudo flat-pebble conglomerates and the silicified limestones. Two types of boulder occur, which differ lithologically and in their faunal composition.

The light-gray, dense type yields the following fossils:

<i>Praealveolina</i> sp. (cf. <i>Praealveolina cre-</i>	<i>Nerinea dubia</i> Blanckenhorn
<i>tacea tenuis</i> Reichel)	<i>N.</i> sp.
Sponge spicules (monactinellid) rare	<i>Cerithium</i> sp.
<i>Anatina(?) orientalis</i> Whitfield	<i>Actaeonella</i> sp.
<i>Patella</i> sp.	
<i>Ceritella bilineata</i> Billings	

The wide range of the few specifically identified peleypods and gastropods—that is, from Aptian to Cenomanian—does not permit a definite age determination of these fossils. The presence of the genus *Praealveolina*, however, which is unknown from pre-Cenomanian deposits, according to M. Reichel,³⁹ establishes a Cenomanian age of the fauna.

³⁷ Blanckenhorn, "Die Bivalven . . . ," *op. cit.*, summarizing table.

³⁸ Blake, *The Stratigraphy of Palestine* . . . , p. 54.

³⁹ "Etude sur les alvéolines 2," *Mém. Soc. pal. Suisse*, Vol. LIX (1937), pp. 135-36.

The faunal composition of the porous pseudo flat-pebble bearing type is different:

Individual corals	<i>Cerithium</i> sp. (cf. <i>Pyrazus elias</i>
<i>Helioporacea</i> (cf. <i>Polytremacis</i>)	Boehm)
<i>Nerinea</i> sp.	<i>Actaeonella</i> sp.

Fragments of colonial corals form the bulk of the fossils. Although the fauna of both boulder types is different in general, the presence of a *Nerinea* type occurring in both suggests that they are derived from the same stratigraphic unit. Since the listed *Cerithium* sp. is only closely related but not identical with *C. elias*, an index fossil of the Lower Cenomanian, no definite statement is possible as to whether the faunal assemblage is Lower or Upper Cenomanian.

CORRELATION

The separation of the Cenomanian from the underlying and overlying deposits was, of necessity, based on lithologic criteria, since fossils are missing in the boundary zones. In the Wadi Sartaba, the contact with the underlying Upper Albian-Vraconian rocks is observable. The boundary line was arbitrarily drawn there at the base of the dolomitic limestone series, which is typical of the Cenomanian rocks. In some places the boundary between the Cenomanian and Turonian beds is sharply marked. This is true where pink mottled Cenomanian dolomites are overlain by the so-called "Mizi helu" facies, which is Turonian in age. Commonly, however, the dolomites grade upward into crystalline limestones which resemble the Upper Turonian facies. A white marble-like coarse limestone, the so-called "Meleke,"⁴⁰ occurs locally, at the top of the presumably Upper Cenomanian in the bore section of the Tur'an plain and south of the Khallet et Tayun on the path to Iksal. This facies represents in the Carmel area the uppermost Cenomanian⁴¹ and in the Jerusalem area the basal Lower Turonian⁴² on the basis of faunal evidence.

The fauna cited above affords the only means of estimating the

⁴⁰ Arabic term meaning the "royal stone."

⁴¹ Blake, *The Stratigraphy of Palestine . . .*, p. 56; J. Vroman, "Geology of the Region of Southwestern Carmel (Palestine)" (Ph.D. dissertation, University of Utrecht, 1938), p. 7.

⁴² Blake, *The Stratigraphy of Palestine . . .*, p. 51; Picard, "The Geology of New-Jerusalem," *Bull. V., Geol. Dept. Hebr. Univ.* (1938).

approximate proportional thickness of the Lower and Upper Cenomanian series. On the basis of the faunal data presented, the strata in which the fauna occurs must be considered as late Lower Cenomanian in age. The stratigraphic position, 190 meters below the top of the Cenomanian, indicates that the underlying 250 meters of the deposit (at least) are Lower Cenomanian in age. The exact thickness of the Upper Cenomanian remains uncertain. Blake⁴³ reports a thickness of 550-750 feet for the Upper Cenomanian of northern Palestine, which indicates an average thickness of 220 meters. In the northern part of Mount Carmel, which lies about 20 kilometers west of the region studied, the thickness of the Upper Cenomanian beds does not exceed 100 meters, according to the same report. It is therefore probable that, of the 190 meters of strata overlying the late Lower Cenomanian fauna, most is late Cenomanian in age. The exclusive presence of the previously mentioned intraformational conglomerates and breccias in the upper 160 meters of the sequence appears to represent additional evidence for a correlation of most of these strata with the Upper Cenomanian. They indicate similar shallow-water conditions as generally observable in the Upper Cenomanian deposits of Palestine-Transjordan.

In conclusion, the Cenomanian sequence is lithologically a predominantly dolomitic series with irregularly interbedded limestones. There exist subordinate, local facies variations. These are indicated by the occurrence of chert nodules and argillaceous limestones in both the lower and upper part of the sequence and by intraformational conglomerates and breccias exclusively in the upper part. On the basis of a late Lower Cenomanian fauna and indications of shallow-water conditions a rough separation of the Lower and Upper Cenomanian strata has been attempted. Additional faunal evidence, however, is necessary for an exact stratigraphic analysis.

TURONIAN

AREAL DISTRIBUTION

The Turonian formation, in contrast to the underlying Cenomanian, is comparatively thin. It crops out generally as a narrow band of well-bedded strata which conformably overlies the Cenomanian.

⁴³ *The Stratigraphy of Palestine . . .*, pp. 54, 58-59.

deposits in all the cited Cenomanian exposures, with the exception of the Mount Tabor horst and the two small outcrops in the cuts of the Wadi M'gata. The Turonian was mapped with the Cenomanian as one unit.



FIG. 7.—Southern escarpment of the Eastern Nazareth Mountains, bordering the Tabor Plain. From the northwest slope of Mount Tabor.

PREVIOUS WORK

In the area studied, Turonian beds were first separated by Blake,⁴⁴ who distinguished in a section from the Jabal Sih: "Mizi helu: Upper Turonian, ?Meleke with *Durania*: Lower Turonian." The occurrence of *Nerinea requieniana* d'Orbigny in the "Mizi helu [Turonian]" of the Jabal Aqaba is cited in the same report.⁴⁵

SUBDIVISIONS

In the following the Turonian sequence is divided into a lower and upper complex. The subdivisions are based on lithologic and faunal criteria.

⁴⁴ *Ibid.*, p. 39.

⁴⁵ *Ibid.*, p. 58.

A. LOWER COMPLEX

Lithology.—The predominant rock type of the well-stratified lower complex is the so-called “Mizi helu,”⁴⁶ a dense brown- and pink-mottled limestone, cream-colored in places. This rock type forms the most characteristic facies type of the Turonian in Palestine. According to Blake,⁴⁷ it is a fine-grained, semi-crystalline rock with the general properties of a lithographic stone. Stylolite seams are common. Marble-like, coarse-grained limestone masses, locally pink mottled, form the rock type of the interbedded rudistite zones. They are probably identical with the “? Meleke” in Blake’s⁴⁸ section from the Jabal Sih. At Khallat et Tayun (southeast of Nazareth) thin, irregularly bedded argillaceous limestones occur intercalated in the Mizi helu. The Mizi helu northeast of Kafr Kanna at some places contains chert nodules bearing foraminifera. Oölites were found in cavities of fossils and in form of small lenses in a fossiliferous Mizi helu bed on the east side of the Jabal Sih.

Fauna.—In the lower complex the following fossils were found:

<i>Miliolidae</i> div. sp.	<i>Praeradiolites maroni</i> Douvillé
<i>Alveolina fraasi</i> (Gümbel)	<i>Radiolites</i> sp.
? <i>Trochomilia</i> sp.	<i>Durania</i> sp.
<i>Coelosmilia</i> sp.	<i>Plicatula</i> cf. <i>reynesi</i> Coquand
<i>Pedinopsis</i> sp.	<i>Nerinea subgigantea</i> Blanckenhorn
<i>Holcypus</i> sp.	<i>N. requieniana</i> d’Orbigny
Echinoid plates and spines	<i>Iteria</i> sp.
Bryozoa	Calcareous algae

Bioherms.—The most abundant fossils are the rudistites, which occur as widespread bioherms and shell breccias. Commonly, there is a single rudistite bioherm, but southeast of Nazareth two separate rudistite zones occur. The lower zone consists of three successive bioherms, of which the middle one was less densely populated. Each bioherm is overlain by re-worked zones, composed principally of rudistite fragments and subordinately of oyster and echinoid remains. In a single instance what appears to be the detrital fan at the outer edge of the lower bioherm zone is exposed. Here (east side of the

⁴⁶ Arabic term meaning “the sweet stone.”

⁴⁷ *The Stratigraphy of Palestine* . . . , p. 106.

⁴⁸ *Ibid.*, p. 39.

Wadi el Haij) the bioherm-bearing zone is replaced by an unusual thick unstratified shell breccia. The upper zone contains only one bioherm, again overlain by a shell breccia. The biotope of the inter-bioherm areas differs considerably from that of the bioherms proper. With increasing distance from the bioherm edge, rudistites and their shell fragments disappear gradually and are replaced by a faunal assemblage, which consists of the above-listed individual corals, echinoids, pelecypods, and gastropods. The local find of fragmentary bryozoans and calcareous algae in an interbioherm assemblage, in close proximity to the bioherm edge, makes it appear uncertain whether these forms belonged originally to the bioherm or inter-bioherm fauna. The faunal assemblage of the shell breccias overlying each of the bioherms indicates temporary overlaps of the inter-bioherm biotopes. These intercalated re-worked zones might be interpreted as indications of differential diastrophic movements.

An alternative explanation may be deduced from two facts: (1) the extreme shallow-water conditions to which the rudistites had been adapted; (2) the limited vertical development of the individual bioherms. It is conceivable that limited vertical growth of the rudistites in such an environment brought the bioherm within the reach of extreme wave action and eventually caused intertidal exposure of the rudistites to the air. A shortening of the food-gathering period due to prolonged closure of the valves may have killed the rudistites, and wave action then destroyed their skeletons. Additional evidence, however, is necessary to decide the issue.

Correlation.—*Alveolina fraasi* was found widely distributed in the area studied in the lower complex, which corresponds stratigraphically to the lower part of the Mizi helu (lower Mizi beds) in the Wadi el Jor at Jerusalem. Specimens collected from the latter locality were originally described by Fraas⁴⁹ as "*Nummulites cretacea*,"⁵⁰ which may be regarded as an important zone fossil in the region studied, since it occurs in both biotopes. Further study in other regions where the Mizi helu facies extends to the top of the Turonian

⁴⁹ *Op. cit.*, pp. 55-56, 83-84.

⁵⁰ C. W. Gümbel, "Über zwei jurassische Vorläufer des Foraminiferen-Geschlechts, *Nummulina* und *Orbitolites*," *Neues Jahrb. f. Min.* (1872), pp. 241-59. Gümbel, who examined specimens collected by Fraas, called them *Alveolina fraasi*.

sequence will show whether *A. fraasi* is restricted to the lower part of the Turonian or is a facies fossil.

Of the specifically identified forms, *A. fraasi* and *P. maroni* are confined to the Turonian. *Praeradiolites maroni* has been reported only from the Lower Turonian of the Lebanon.⁵¹ The remaining forms are of little value in age determination, owing to their extended stratigraphic range.

B. UPPER COMPLEX

Lithology.—The upper complex is a well-stratified series of pinkish mottled, crystalline limestones. Beds of the Mizi helu type commonly occur intercalated in the basal part of this series. Argillaceous limestones and dolomites are locally developed.

The crystalline limestone beds of the upper complex grade into the chalky limestones of the overlying Santonian deposits.

Fauna.—The upper complex yields the following fossils:

<i>Rhynchonella plicatilis</i> var. <i>bohemica</i>	<i>Pycnodonta vesicularis</i> Lamarck
Schloenbach	<i>Ostrea</i> div. sp.
<i>Exogyra columba</i> Lamarck	Fish teeth and bones
<i>Pycnodonta vesiculosa</i> Sowerby	

A pronounced faunal change marks the upper complex. The Rudistaceae with their faunal associates are replaced by a monotonous fauna of Rhynchonellidae, Ostreidae, and fish remains. Beds with *Ostrea vesicularis* mark commonly the passage zone to the overlying Santonian.

Correlation.—*Rhynchonella plicatilis* var. *bohemica* is confined to the lower part of the upper complex. The species can be regarded as a true zone fossil, as its areal distribution in the Eastern Nazareth Mountains shows. According to N. Schloenbach⁵² and H. Scupin,⁵³ this form occurs in the Lower and Middle Turonian of central Europe and France. The Ostreidae are of little stratigraphic value because of their extended range.

The fossil content, though meager, establishes the upper complex

⁵¹ Douvillé, *loc. cit.*

⁵² "Kleine paläontologische Mittheilungen, III. Die Brachiopoden der böhmischen Kreide," *Jahrb. d. k. k. geol. Reichsanst* (Wien), Vol. XVIII (1868).

⁵³ "Die Löwenberger Kreide und ihre Fauna," *Palaeon. Suppl.*, Vol. VI (1912-13), pp. 246-47.

as Turonian in age. The limited number of forms in both the lower and upper complex which are confined to the Turonian confirms the general observation that the Turonian fauna in Palestine, in contrast to that of Syria and Transjordan, is not well defined.⁵⁴

Consideration of Blake's section of the Jabal Sih shows that both his Upper and Lower Turonian are part of what we have designated "Lower Turonian complex." Picard describes similar beds with *Ostrea* sp. and *Rhynchonella* sp. from the Western Nazareth Mountains.⁵⁵ He suggests a Santonian age for these rocks, a correlation based exclusively on lithologic criteria.

Thickness.—The Turonian beds have a total thickness of 20–30 meters.

SENONIAN

GENERAL STATEMENT

The Senonian comprises a sequence of unstratified chalks, marls, chalky and pure limestones with a distinctive fauna. There is no definite boundary toward the underlying upper complex of the Turonian because of the grading facies previously mentioned. The upper boundary is commonly well marked by the appearance of the well-bedded chalky limestone of the "transitional" Cretaceous-Eocene series. On the basis of faunal evidence the Santonian, Campanian, and Maestrichtian stages, as defined in the Senonian key section in the Judean Desert,⁵⁶ are recognizable. Difficulties, however, were experienced in attempting to separate the Campanian section from that of the Maestrichtian, owing to the localized occurrence of fossils, facies, and faunal changes and extensive masking of the deposits by "nari."

AREAL DISTRIBUTION

The areal extent of Senonian exposures is shown on the geological map (Fig. 2).

PREVIOUS WORK

A comparison between the accompanying map and the one by Blanckenhorn⁵⁷ shows that most of the areas marked by Blancken-

⁵⁴ Blanckenhorn, "Geologie Palästinas . . .," *op. cit.*, p. 10.

⁵⁵ Picard, "Zur Geologie der Kischon-Ebene," *op. cit.*, p. 9.

⁵⁶ Picard, *Geological Research in the Judean Desert* (Jerusalem, 1931), p. 1.

⁵⁷ "Kurzer Abriss . . .," *op. cit.*, map.

horn as Senonian are Eocene in age. Blanckenhorn's view was adopted in the later maps of Fohs,⁵⁸ Range,⁵⁹ and Dubertret.⁶⁰ In a composite section of the sequence at the Jabal Sih, Blake⁶¹ recognizes the Santonian, Campanian, and Maestrichtian stages of the Senonian. Among "good examples" of the Maestrichtian, Blake⁶² cites an outcrop north of Nazareth which, according to the following discussion, exposes deposits of the transitional Cretaceous-Eocene to Lower Eocene series. The age of another occurrence of the same series at the east side of Jabal Sih⁶³ is given as "Lower Middle Eocene or Maestrichtian."

A. SANTONIAN (CONIACIAN)

Lithology.—The Lower Senonian consists of massive white chalky limestones, which in places are pink mottled. This rock type, the so-called "Kakuhle," represents the characteristic Santonian facies of Palestine. On the basis of its uniform lithology throughout the area studied, the Santonian can be separated even where it does not carry megascopic fossils.

Thickness.—The thickness of the Santonian is 6–10 meters.

Fauna.—The following fossils were found only in the northern belt of outcrops, near Kafr Kanna and Lubyā:

<i>Protocardia</i> sp.	<i>Mortonicerās</i> cf. <i>quattuornodosum</i> var.
<i>Ostrea</i> sp.	<i>planulata</i> Lasswitz
<i>Dentalium cretaceum</i> Conrad	<i>Gauthiericeras austinense</i> F. Roemer
	<i>Gauthiericeras austinense</i> var. <i>minima</i> Lasswitz

Correlation.—According to Blanckenhorn,⁶⁴ *M. quattuornodosum* and *G. austinense* are characteristic forms of the Santonian of Palestine. They had previously been described from the Austin chalk of Texas. The impression of a large ammonite mold, observed at the

⁵⁸ *Op. cit.*, map.

⁵⁹ "Wissenschaftliche Ergebnisse einer geologischen Forschungsreise nach Palästina im Frühjahr 1928," *op. cit.*, sketch map.

⁶⁰ *Op. cit.*, map.

⁶¹ *The Stratigraphy of Palestine* . . . , p. 39.

⁶² *Ibid.*, p. 46.

⁶³ *Ibid.*, p. 39.

⁶⁴ "Geologie Palästinas . . . ," *op. cit.*, p. 11.

fossil occurrence of Kafr Kanna, indicated the presence of *Texanites quinquenodosus*, the common zone fossil of the Santonian of Palestine. Thus the Santonian may be said to be both lithologically and faunally well marked in the Eastern Nazareth Mountains.

B. CAMPANIAN

Lithology.—In contrast to the uniform lithology of the Santonian, the lower part of the Campanian sediments varies considerably in lithology. Iron-stained, foraminiferal marls, hard chalky limestones, and soft white chalks form the basal Campanian in the few exposures observed. A lateral tracing of the different facies was impossible, since most of the rocks are hidden by a sari cover up to 2 meters in thickness. The overlying deposits consist uniformly of soft chalks which locally are highly bituminous. A dark-brown flint bed is intercalated in these chalks throughout the area studied. Locally, in the Wadi Ramiq, however, three flint beds were found, underlain by an oyster bed, which consists of thin shells of *P. vesicularis*. Oyster beds and the parallel orientation of shells of *D. cretaceum* indicate shallow-water conditions, with the sea floor temporarily, at least, above wave base.

Fauna.—The lower Campanian deposits are highly fossiliferous. The following fossils were collected predominantly from this zone at Kafr Kanna, in the Tur'an plain (southern border) in the Wadi Umra Jubeil, at Arab S'Beih, and in the vicinity of Nazareth:

<i>Magas</i> cf. <i>geinitzi</i> Schloenbach	<i>Pecten delumbris</i> Conrad
<i>M.</i> sp.	<i>Pycnodonta vesicularis</i> Lamarck
<i>Leda perdit</i> a Conrad	<i>Dentalium cretaceum</i> Conrad
<i>Arca fabiformis</i> Conrad	<i>D. octocastatum</i> Fraas
<i>A. (Grammatodon) parallelus</i> Conrad	<i>Natica</i> sp.
<i>Astarte undulosa</i> Conrad	<i>Scalaria</i> sp.
<i>Crassatella</i> cf. <i>falconieri</i> Lartet	<i>Turritella maussi</i> Lartet
<i>C. rothi</i> Fraas	<i>Fusus</i> sp.
<i>C.</i> cf. <i>larteti</i> Picard	<i>Volutilithes</i> sp.
<i>Liopista</i> sp.	<i>Ammonites</i> sp. ind.
<i>Meretrix andersoni</i> B. Newton	<i>Ancycloceras</i> sp.
<i>Lucina</i> cf. <i>dachelensis</i> Wanner	<i>Scaphites</i> sp.
<i>Corbula</i> cf. <i>paracrassa</i> Wade	<i>Baculites</i> sp.
<i>Inoceramus</i> sp.	Fish remains

The faunal character is Mediterranean with local eastern Mediterranean features.

Correlation.—With the exception of the brachiopods cited, which represent a new faunal element, most of the forms are commonly known from the Upper Senonian of Palestine and Egypt.

C. MAESTRICHTIAN

Lithology.—In the upper part of the Senonian sequence changing facies conditions recur. Commonly the Maestrichtian is represented by a white (in places, hard) chalky limestone, which, because of the abundance of *Baculites* casts, is characterized as "*Baculites* facies." At some places the bituminous chalk facies of the Upper Campanian extends without visible change up to the top of the Maestrichtian (Wadi Ramiq). In this facies the bitumen content increases locally compared with that in the Campanian (Bir Kapshane). Iron-stained foraminiferal marls, lithologically identical with the Lower Campanian facies, form the uppermost Maestrichtian near Sajara and north of Er Reina. Locally, flint beds were observed in the Maestrichtian.

Bone-bed-like concentrations of fish remains, associated with granules of phosphate, occur as small lenses in the chalky limestones. Fragments of bones, scales, and teeth of fishes form the bulk of the constituents. Coprolites and fragments of oyster shells are less common. The interstitial groundmass is predominantly composed of lenticules and oölites of phosphate and, to a minor extent, of foraminifera of the size of the phosphate granules.

Facies discussion.—The sporadic occurrence of both flint and phosphate likewise characterizes the Maestrichtian in the standard area, the Judean Desert. There flint occurs in numerous compact beds and bands of nodules, and the phosphate is found in one or two thick zones.⁶⁵ A comparison of the Maestrichtian sections of the Judean Desert, of the Wadi Farah region⁶⁶ (Samaria), and of the area studied demonstrates a progressive decrease in the thickness of the Maestrichtian deposits and, more especially, of the flint and

⁶⁵ Picard, *Geological Researches* . . . , p. 31.

⁶⁶ Picard, "Zur Geologie des Gebietes zwischen Gilboa und Wadi Fara," *Centralbl. f. Min. Geol. Pal.*, Abt. B (1934), p. 25.

phosphate components from the Judean Desert to the Eastern Nazareth Mountains. The same observation was made by M. Avnimelech⁶⁷ by comparing the Maestrichtian of the Judean Desert with that of the western flank of the Judean arch.

There is the question as to what the different facies indicate. Picard pointed out that the formation of the phosphate and flint deposits, as well as the presence of abundant semisessile faunal elements, indicates extreme shallow-water conditions of the Maestrichtian facies in the Judean desert area. There are ample data to show that the Maestrichtian sea of the eastern Nazareth area was also shallow. Such evidence may be seen in the sporadic occurrence of phosphatic bone-bed lenses, foraminiferous sands, the abundance of *Ostreidae*, the local concentrations of uniform-sized specimens of genus *Baculites*, and the parallel orientation of elongated shells of gastropods, scaphopods, and fish bones. In contrast to the extreme shallow-water conditions indicated for the entire Judean desert area, only occasional, local indications that the sea floor was above wave base are observable in the area studied. The water depth, there, may have been near the wave base.

The amount of uplift responsible for the shallowing of the sea in Maestrichtian time, compared with the Campanian, was therefore much greater in the Judean desert area than in the region studied. These intensified diastrophic movements at the end of Cretaceous time resulted in the complete emergence of parts of Judea and Transjordan⁶⁸ as an island, in which the Judean desert area was centrally situated. In the area studied, however, sedimentation went on, with probably minor local exceptions, up to the end of the Middle Eocene. The facies conditions in the area were, therefore, more typical of the epicontinental Maestrichtian sea than those of the standard area, the Judean Desert, which were rather local in character.

Fauna.—The Maestrichtian sediments are, like those of the Campanian, rich in fossils. The *Baculites* facies may be regarded as diag-

⁶⁷ "Études géologiques dans la région de la Shéphélah en Palestine" (thèse, Grenoble: Allier Père et Fils, 1936), pp. 43-45.

⁶⁸ The extent of the island is shown on the sketch map by Blake in "Old Shore Lines of Palestine," *op. cit.*, p. 72.

nostic for the Maestrichtian, just as is the case in the Judean desert area.

The following fossils were collected in the vicinity of Nazareth, Er Reina, Kafr Kanna, and Esh Shajara:

<i>Cyclocyathus</i> (?) sp. Felix	<i>Dentalium octocostatum</i> Fraas
<i>Serpula</i> aff. <i>subtorquata</i> Münster*	<i>D. cretaceum</i> Conrad
<i>Leda perditia</i> Conrad	<i>D.</i> sp.
<i>Grammatodon</i> (?) <i>Arca parallelus</i> Conrad	<i>Natica</i> aff. <i>farafrensis</i> Wanner†
<i>Arca fabiformis</i> Conrad	<i>Turritella maussi</i> Lartet
<i>Astarte undulosa</i> Conrad	<i>T. reyi</i> var. <i>seetzeni</i> emend. Blanckenhorn†
<i>Crassatella</i> cf. <i>rothi</i> Fraas	<i>Mesalia foucheri</i> Pervinquiere*
<i>C. falconieri</i> Lartet	<i>Cerithium</i> aff. <i>pseudoclathratum</i> d'Orbigny*
<i>Liopista</i> sp.	<i>Helicaulix</i> (<i>Aporrhais</i>) cf. <i>stenoptera</i> Goldfuss*
<i>Lucina safedensis</i> Conrad	<i>Aporrhais</i> sp. nov.(?)
<i>L. dachelensis</i> Wanner†	<i>Ammonites</i> sp.
<i>L. sahara</i> Fraas*	<i>Hamites</i> sp.
<i>Meretrix andersoni</i> B. Newton	<i>Heteroceras</i> sp.
<i>Cytherea</i> aff. <i>rohlfsi</i> Fraas*	<i>Baculites</i> sp.†
<i>Corbula</i> cf. <i>paracrassa</i> Wade	<i>Pseudochloenbachia</i> sp.
<i>Inoceramus regularis</i> d'Orbigny	<i>Ancycloceras</i> (?) <i>safedensis</i> Conrad
<i>Pecten nilssonii</i> Goldfuss	<i>Scaphites</i> sp.
<i>Pycnodonta vesicularis</i> Lamarck	<i>Aptychus</i> sp.
<i>Pecten spatulatus</i> (Ravn)	<i>Corax pristodontus</i> Agassiz*
<i>Ostrea</i> sp. (cf. <i>O. nicaisei</i> Coquand)	Fish remains

* Known from the Maestrichtian of other countries.

† Known from the Maestrichtian of the Judean Desert according to Picard.

The fauna is readily distinguishable from that of the Campanian, especially where the *Baculites facies* is developed.

Thickness.—The Maestrichtian and Campanian sediments have a total thickness of 60–80 meters. No figures for the thickness of each stage were obtainable, as pointed out above. From partial sections it can be estimated, however, that the thickness of the Maestrichtian is less than 10 meters.

Danian(?).—The uppermost 1–2 meters of the Maestrichtian sediments are free of megascopic fossils. Since the lithology does not

change in this unfossiliferous part of the sequence, these rocks were provisionally included in the Maestrichtian. They may represent, however, the equivalent of the Danian.

CRETACEOUS HISTORY

The geologic history of the Eastern Nazareth Mountain area can be traced back to the Vraconian stage. At this time the Tethys Sea invaded the Nazareth area, which, geographically considered, is a marginal part of the Arabian shield. Although no earlier deposits are exposed, it can be concluded from the approximate course of the shorelines of the Lower Cretaceous sea⁶⁹ that there were two earlier marine invasions in Aptian and early Albian time followed shortly by retreat. In contrast to these oscillations, the submergence in Vraconian time was the initial phase of a continuous widespread transgression, the so-called "Upper Cretaceous" or "Cenomanian transgression," recognized in many parts of the world.

The Vraconian sea advanced from the west and was, at the beginning, very muddy, owing to the proximity of the shoreline to the east (about 40 km.). Toward the end of the stage a clearing of the sea took place. Thus, sedimentation in early Cenomanian time was practically limited to chemical and organic precipitates, calcareous sediments which have been altered predominantly to dolomitic rocks, possibly diagenetically. At this time the progressive subsidence of this part of the shelf since Vraconian time reached its maximum, and the sea was relatively deep and characterized by local sponge reefs. In late Cenomanian time recurrent movements caused a shallowing of the sea, and there are local indications that the sea floor was above wave base. These shallow-water conditions prevailed through Turonian time. They favored the development of extensive rudistite reefs in the clear water of the first part of the Turonian.

The limestones of the Turonian grade upward into chalky limestones of the Santonian stage, at the beginning of Senonian time, and into chalks and marls of the following Campanian and Maestrichtian stages. These fine calcareous foraminiferal muds appear

⁶⁹ *Ibid.*, p. 70, Fig. 1; also p. 72.

to represent far-offshore deposition on the shelf. During Santonian time the sea seems to have deepened slightly, but the local concentration of Ostreidae shows that it was still relatively shallow. The occurrence in the Tethys Sea of a few ammonite species of the genera *Mortoniceras* and *Gauthiericeras*, characteristic of the far-distant Texas areas, appears remarkable. The following stages of the Senonian, the Campanian, and the Maestrichtian are characterized by an abundance of organic remains (especially of mollusks), which is typical for the entire Palestinian part of the shelf. A progressive shallowing of the sea during both stages is clearly evident, with the climax in late Maestrichtian time. This progressive shallowing, as evidenced in the region studied, was only a minor reflection of those uplift movements whose center was farther southeast between Nablus and Beersheba on the Palestinian side and in the northeastern adjacent area of Transjordan. The continuance of these movements finally resulted in complete emergence of this area as an island in the early Eocene sea. In the region studied, however, continuous sedimentation seems to have prevailed from late Maestrichtian to early Eocene time, though local diastems may be present.

